Space Weather Technical Forecast

Issued on Tuesday, 29 March 2022 at 13:30 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Chance of further M-class flares throughout. Slight chance of further S1 or above radiation storms. G1-G2/Minor-Moderate geomagnetic storms are expected on Day 3 (31 March), with a Chance of a G3/Strong storm.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Moderate, with further M1 flares over the past 24 hours, these originating from AR2975.

There are currently seven sunspot regions on the visible disc. AR2975 remains magnetically complex and continues to develop, with further growth in its leading spots, and the presence of two delta spots. AR2978 (Eho/Beta) continues to rotate from the SE limb and is showing minor trailer spots. AR2976 in the northeast quadrant is currently the largest sunspot, although its delta spot has recently faded. AR2977 (NW quadrant) and AR2979 (SE quadrant), are now both classified Bxo/Beta, and have shown signs of decay. AR2974 (SW quadrant) remains a simple and stable uni-polar spot. Newly numbered AR2980 is currently a small bi-polar group in the northwest quadrant. An Earth directed CME associated with yesterday's (28 March) M4 flare, has been analysed and modelled, which shows an arrival at Earth on Day 3 (31 March). A further halo CME followed an M1 flare (also from 2975) around 28/1920UTC, which has also been analysed, and these show a combined CME arriving at Earth on Day 3 (31 March).

Solar Wind / Geomagnetic Activity: The solar wind, as observed by DSCOVR at L1, declined from peaks of around 520km/s to around 410km/s. The density has been mostly at average levels. The strength of the IMF, Bt, has been at weak at 2-5nT. The north-south component, Bz, weakly variable between +5 and -3 nT. The Phi angle was predominately positive (away from the Sun), but with brief transitions to negative (towards the Sun). Geomagnetic activity was Quiet (Kp 1-2).

Energetic Particles / Solar Radiation: The high energy proton flux (10MeV) measured at GOES-16 became enhanced soon after the M4 flare with an S1/Minor radiation storm, which peaked at 18pfu at 28/1450UTC, before dropping below the S1 threshold (10pfu) after 28/2115UTC.

The high energy (greater than 2 MeV) electron flux as observed by GOES-16 at GEO rose from background to Moderate levels, with a peak of 362pfu at 28/2040 UTC, following recent coronal hole high speed stream influence. The observed fluence at 29/0000 UTC was 8.21e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity is expected to be mostly Low, but with a chance of further M-class flares, and perhaps a slight chance of an isolated X-class flare. This risk mainly from region 2975.

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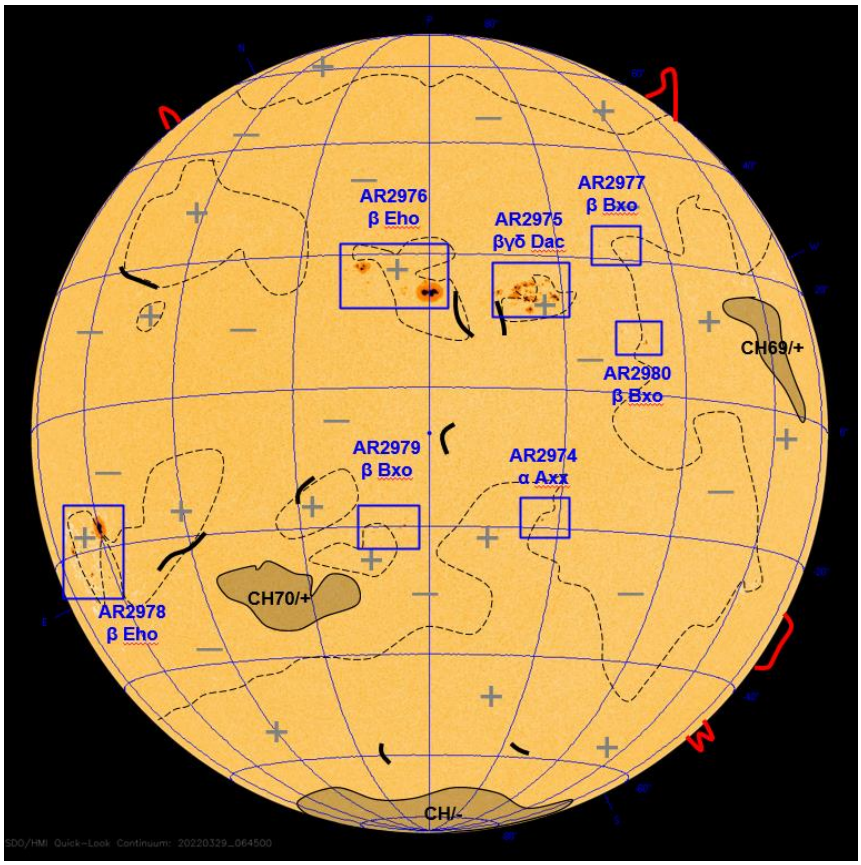
Solar Wind / Geomagnetic Activity: The next enhancement to the solar wind is expected to come from the 28th March CME(s), which have been analysed and modelled, and these show a combination of the two CMEs, which are likely to arrive at Earth on Day 3 (31 March). Quiet to Unsettled conditions are expected until Day 3 (31st Mar), when Active to G1-G2/Minor-Moderate storm periods are expected, with a chance (30%) of a G3/Strong Storm and a slight chance (10%) of a G4/severe storm. Disturbed geomagnetic conditions are expected to continue into Day 4 (1st April) due to influence from the CME(s).

Energetic Particles / Solar Radiation: The continued activity of 2975 in particular gives the slight chance of further potential enhancements above the S1 threshold during the period, particularly on Day 1 (29th) as proton flux levels are still recovering from the S1 event that took place yesterday (28 March). A rising trend in electron flux values is possible through the coming days, perhaps reaching High levels at the diurnal peaks on Days 1 and 2 (29th and 30th March). From Day 3 (31st March) confidence becomes low, due to the arrival of the 28 March CME(s), which are likely to reduce flux levels. The associated 24 hour fluence is likely to follow a rising trend for the next 2 days, but remain below the Active (1e8 integrated pfu) threshold. Again beyond this confidence becomes low, as fluence levels are likely to become erratic due to CME influence. REFM is considered to be giving reasonable guidance in the short term, showing a rising trend but remaining below Active levels.

Figure 1. Solar Analysis Valid 29/0645 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

Solar wind speeds have declined from peaks of around 520km/s to around 410km/s at present, due to waning coronal hole influence. The next enhancement is expected to come from the 28th March CME(s), which are expected to arrive, as a combined CME, at Earth, on Day 3 (31 March).

Quiet to Unsettled conditions are expected until Day 3 (31st Mar), when Active to G1-G2/Minor-Moderate storm periods are expected, with the Chance (30%) of a G3/Strong Storm and a Slight Chance (10%) of a G4/Severe Storm. Disturbed geomagnetic conditions are expected to continue into Day 4 (1st April).

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	1	1	80	60
Strong	G3	No	1	1	30	30
Severe	G4	No	1	1	10	10
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
28/1624UTC	Halo	M4 flare 28/1129 UTC	AR2975	550	31st March	G1-G2 expected, with a Chance of G3
29/0108 UTC	Halo	M1 flare 28/1920 UTC	AR2975	722	31st March	Combines with the above CME

Figure 2: ENLIL (top) shows the combined March 28th CMEs arriving at Earth on Day 3 (31 March). Ensemble (bottom) shows the spread members in the expected CME(s) arrival times on 31st March.

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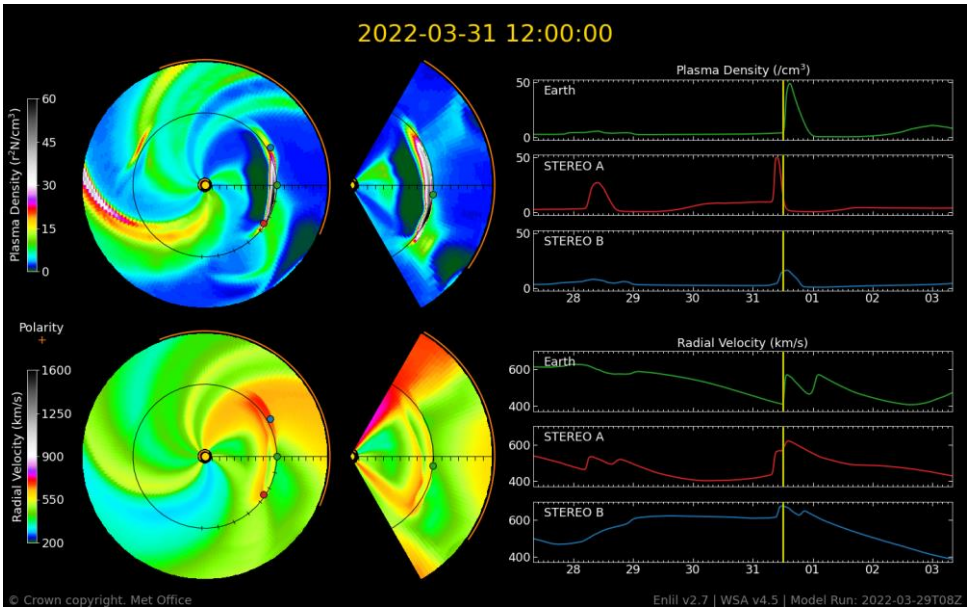

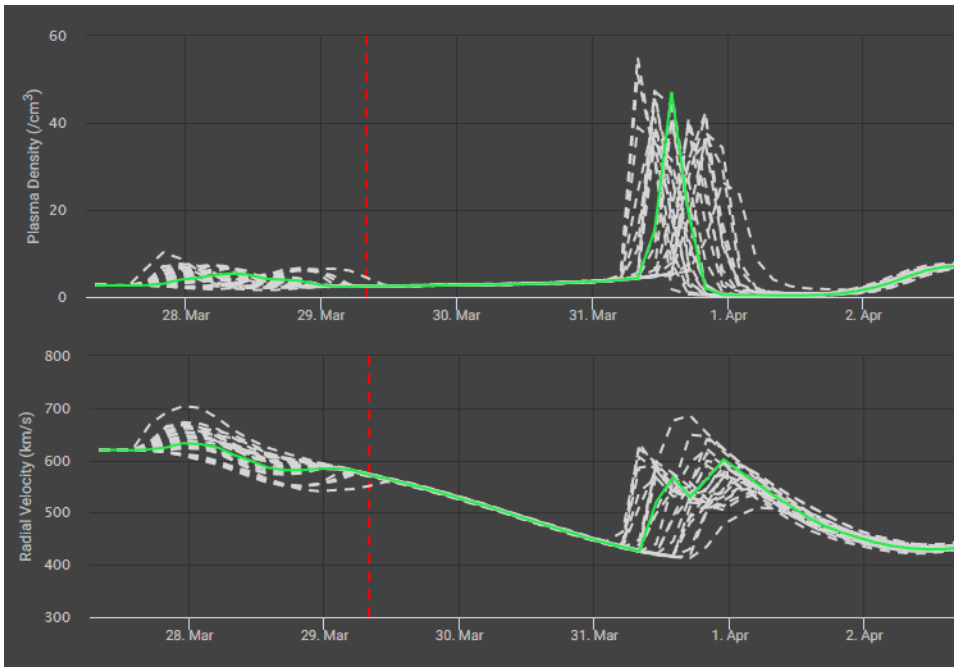

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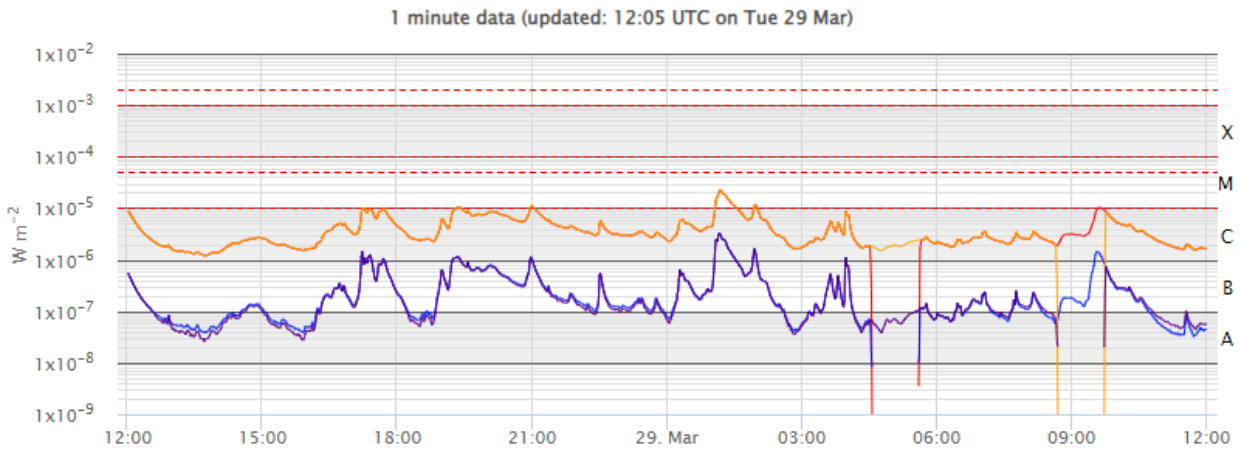
Radio Blackouts - X-Ray Flares:
Solar activity has been Moderate, with an M4 flare at 28/1129UTC, originating from AR2975. This spot region has also subsequently produced several more M1 flares.

There are currently seven sunspot regions on the visible disc. AR2975 remains magnetically complex and continues to develop, with further growth in its intermediate spots, and the presence of two delta spots. AR2978 (Eho/Beta) continues to rotate from the SE limb and is showing minor trailer spot emergence. AR2976 in the northeast quadrant is currently the largest sunspot, although its delta spot within the penumbra of the leading spot has faded. AR2977 (NW quadrant) and AR2979 (SE quadrant), are now both classified Bxo/Beta, and have shown signs of decay. AR2974 (SW quadrant) remains a simple and stable uni-polar spot. Newly numbered AR2980 is currently a small bi-polar group in the northwest quadrant.

Solar activity is expected to be mostly Low, but with further M-class flares likely, and perhaps a slight chance of an isolated X-class flare. This risk mainly from region 2975.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	60	60	60	60
Very Active	R3 to R5 X Class	No	15	15	15	15

Figure 3: GOES-16 X-Ray flares, which shows M-class flares originating from AR2975.



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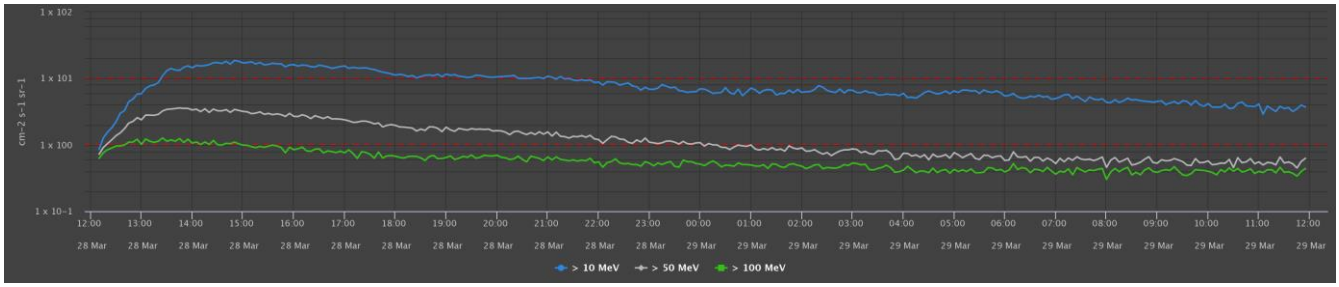
Solar Radiation Storms - (High Energy Protons):
The high energy proton flux (10MeV) measured at GOES-16 became enhanced soon after the M4 flare with an S1/Minor radiation storm, which peaked at 18pfu at 28/1450UTC, before dropping below the S1 threshold (10pfu) after 28/2115UTC. The 100MeV flux also peaked at 1.27pfu at 28/1325UTC. The continued activity of 2975 in particular gives the slight chance of further potential enhancements above the S1 threshold during the period, particularly on Day 1 (29th) as proton flux levels are still recovering from the S1 event.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	Yes	20	10	10	10
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: GOES-16 Proton Flux – shows the >10 Mev and >100 MeV levels elevated on March 28th which occurred after the M4 flare from AR2975. Proton flux remains slightly elevated today, but remain below the Active thresholds.



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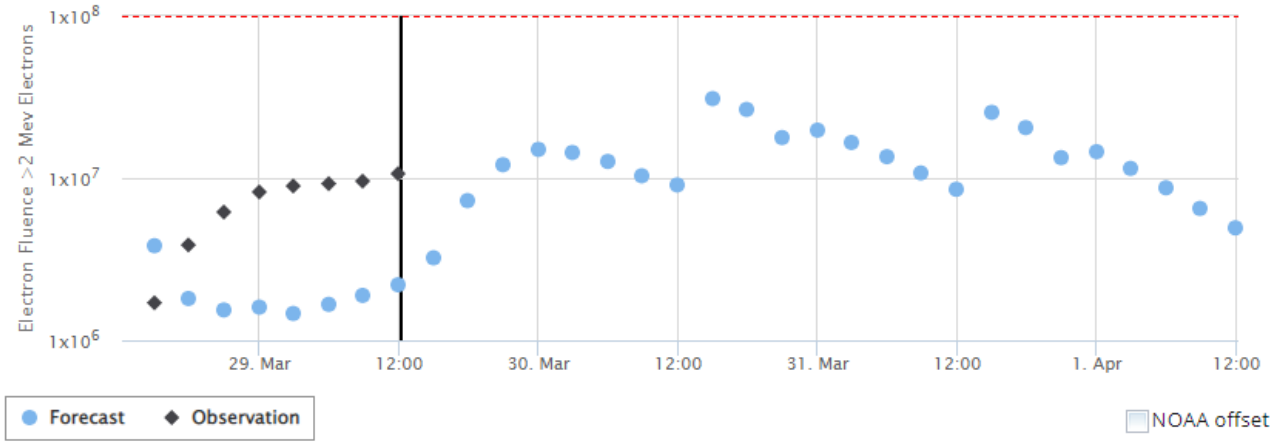
High Energy Electrons Event (≥ 2MeV):
The high energy (greater than 2 MeV) electron flux, as observed by GOES-16 at GEO, rose from background to Moderate levels, with a peak of 362pfu at 28/2040 UTC, following recent coronal hole high speed stream influence. A rising trend in electron flux values is possible through the coming days, perhaps reaching High levels at the diurnal peaks on Days 1 and 2 (29th and 30th March). From Day 3 (31st March) confidence becomes low, as the 28th March CME(s). which are expected to arrive at Earth on Day 3 (31 March) is likely to reduce flux levels.

The associated 24 hour fluence is likely to follow a rising trend for the next 2 days, but remain below the Active (1e8 integrated pfu) threshold. Again beyond this confidence becomes low, as fluence levels are likely to become erratic due to CME influence. REFM is considered to be giving reasonable guidance in the short term, showing a rising trend but remaining below Active levels.

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	10	20	20	20
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	5

Figure 5: REFM for electron fluence – observations and forecast. Steady rise throughout, but low confidence due to the onset of the CME(s) on Day 3 (31 March).



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